MIKE SHE Demonstration

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1 Introduction

This paper is intended as a background paper to support a demonstration of the MIKE SHE modeling system. The paper gives a brief description of the hydrological processes covered by MIKE SHE, and presents briefly the graphical user interface and the principles behind its design. MIKE SHE has been applied extensively over the past 20 years and the process descriptions included today reflects the need that has arisen during many different types of applications. Similarly, the GUI that has been build for MIKE SHE is based on extensive feedback from users.

2 Process-based Hydrologic Modeling

MIKE SHE, in its original formulation, could be characterized as a deterministic, physics-based , distributed model code. It was developed as a fully integrated alternative to the more traditional lumped, conceptual rainfall-runoff models. A physics-based code is one that solves the partial differential equations describing mass flow and momentum transfer. The parameters in these equations can be obtained from measurements and used in the model. For example, the St. Venant equations (open channel flow) and the Darcy equation (saturated flow in porous media) are physics-based equations.

There are, however, important limitations to the applicability of such physics-based models. For example,

- it is widely recognized that such models require a significant amount of data and the cost of data acquisition may be high;
- the relative complexity of the physics-based solution requires substantial execution time;
- the relative complexity may lead to over-parameterized descriptions for simple applications; and
- a physics-based model attempts to represent flow processes at the grid scale with mathematical descriptions that, at best, are valid for small-scale experimental conditions.

Therefore, it is often practical to use simplified process descriptions. Similarly, in most watershed problems one or two hydrologic processes dominate the watershed behavior. For example, flood forecasting is dominated by river flows and surface runoff, while wetland restoration depends mostly on saturated groundwater flow and overland flow. Thus, a complete, physics-based flow description for all processes in one model is rarely necessary. A sensible way forward is to use physics-based flow descriptions for only the processes that are important, and simpler, faster, less data demanding methods for the less important processes. The downside is that the parameters in the simpler methods are usually no longer physics meaningful, but must be calibrated-based on experience.

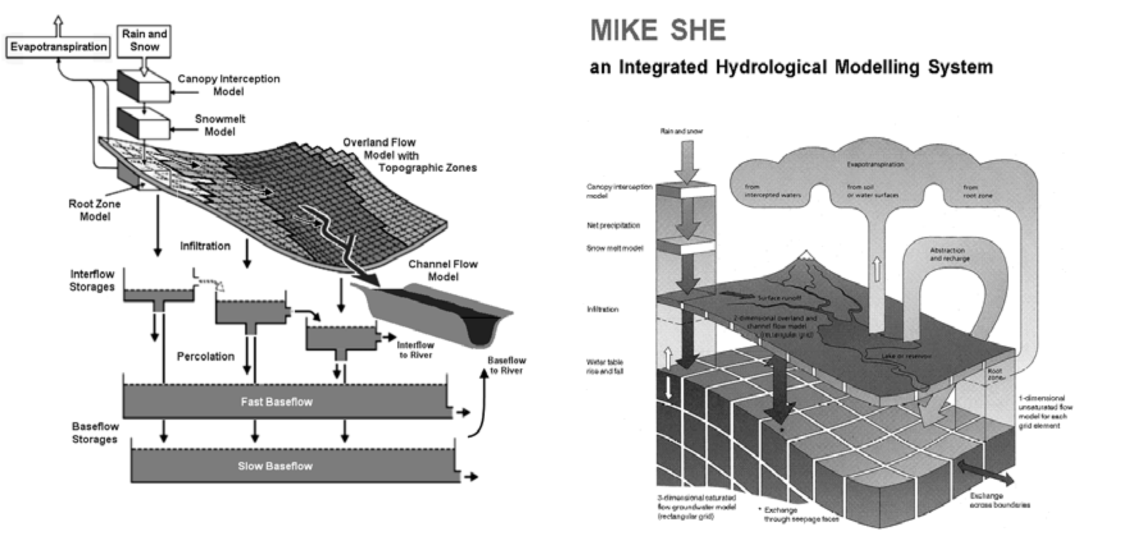
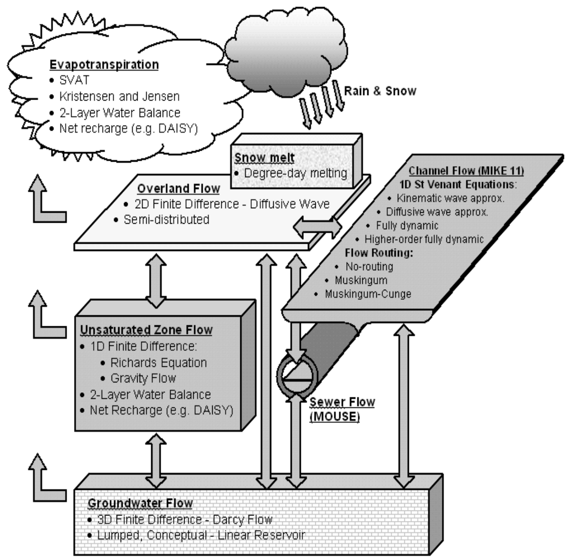


Figure 1. Two Schematic representation of MIKE SHE, a) the conceptual components in MIKE SHE - semi-distributed overland flow and linear reservoir groundwater models; and b) a fully distributed representation.

The process-based, modular approach implemented in the original SHE code has made it possible to implement multiple descriptions for each of the hydrologic processes. In the simplest case, MIKE SHE can use fully distributed conceptual approaches to model the watershed processes (Figure 1a). For advanced applications, MIKE SHE can simulate all the processes using physics-based methods. Alternatively, MIKE SHE can combine conceptual and physics-based methods-based on data availability and project needs. The flexibility in MIKE SHE's process-based framework allows each process to be solved at its own relevant spatial and temporal scale. For example, evapotranspiration varies over the day and surface flows respond quickly to rainfall events, whereas groundwater reacts much slower. In contrast, in many non-commercial, research-oriented integrated hydrologic codes (e.g. MODFLOW HMS, Panday et al., 1998; InHM, Sudicky et al., 2002), all the hydrologic processes are solved implicitly at a uniform time step, which can lead to intensive computational effort for watershed scale models.

The rest of this section outlines the hydrologic processes included in MIKE SHE and a brief description of each of the current methods available for each process (see Figure 2 for a schematic overview of the processes and methods in MIKE SHE). More detailed mathematical descriptions of the processes are available in the MIKE SHE Reference manual, which can be downloaded from the DHI web site. Further information on more specialized functions, such as macro pore flow, can also be found here. More general information on the hydrologic processes can be found in relevant hydrology textbooks (e.g. Maidment, 1992).



The processes are presented in the following order:

1. Precipitation and Evapotranspiration
2. Unsaturated Flow
3. Overland Flow
4. Channel Flow
5. Pipe and Sewer Flows
6. Saturated Groundwater Flow
7. Agriculture, and
8. Water Quality,

Figure 2. Schematic view of the process in MIKE SHE, including the available numeric engines for each process. The arrows show the available exchange pathways for water between the process models

2.1 Precipitation and Evapotranspiration

The atmospheric processes that drive the hydrological cycle are generally not modeled explicitly in watershed models. This is the case with MIKE SHE, although coupling of MIKE SHE with numerical weather models is being explored in current research projects. Precipitation is usually a direct input in MIKE SHE, whereas radiation and water vapor transport in the atmosphere is typically bound up in evapotranspiration (ET). Evapotranspiration refers to the sum of the processes of direct evaporation from free water surfaces and transpiration of sub-surface water either directly or via plants. Evapotranspiration is an important component of the water balance. Evapotranspiration can be 70% of rainfall in temperate climates and even exceed annual rainfall in arid areas (Bedient and Huber, 2002).

Evaporation occurs from all free water surfaces, which not only includes lakes and rivers, but also rainfall trapped on leaves, as well as snow surfaces. Evaporation from the soil is controlled by the soil wetness, soil hydraulic properties and the location of the groundwater table. Transpiration, on the other hand, is strongly related to plant physiology - the depth of the roots, the ability of the roots to extract water from soils, the characteristics of the leaves, etc. Plants can regulate their transpiration depending on the availability of water, which means that transpiration is also a function of the soil moisture content in the unsaturated zone. Thus, ET can have a high degree of spatial variation that changes daily and seasonally, but also in response to climate and land use change. ET and infiltration to the unsaturated zone together determine the timing and magnitude of groundwater recharge, as well as overland flow generation.

MIKE SHE calculates the Actual ET. This is different from the Potential ET and the Reference ET. Potential ET is the theoretical maximum amount of ET - that is the amount of evaporation from a large open body of water under existing atmospheric conditions. Reference ET is the theoretical maximum ET from an idealized reference grass crop that has as much water as it needs (Shuttleworth, 1992). The various ET methods in MIKE SHE differ only in their data requirements and the way they determine Actual ET.

2.1.1 Soil Vegetation Atmosphere Transfer (SVAT)

This MIKE SHE land surface model is a two-layer system (soil and canopy) linked together by a network of resistances (Shuttleworth and Wallace, 1985; Shuttleworth and Gurney, 1990). The model consists of a single, semi-transparent, canopy layer located above the soil layer, such that the only way for heat and moisture to enter or leave the soil layer is through the canopy layer. According to the resistance analogy, the fluxes of latent and sensible heat between nodes are driven by differences in humidity and temperature, respectively, and controlled by a number of resistances. The resistances depend on the internal state of the land-surface-vegetation system as well as the atmospheric conditions. Compared to the original model structure proposed by Shuttleworth and Wallace (1985), MIKE SHE's two-layer model has been extended to include evaporation and sensible heat flux from ponded water on the soil surface and on the leaves. Two-layer models have been successfully tested for many different types of vegetation and under different climatic conditions (e. g. Daamen, 1997; Iritz et al., 1999; van der Keur et al. 2001; Lund and Soegaard, 2003; Boegh et al., 2004). The primary advantage of such a model is that Actual ET is calculated directly from standard meteorological and vegetation data. Reference ET is not a required input.

2.1.2 Kristensen and Jensen Method

The Kristensen-Jensen model (Kristensen and Jensen, 1975) is based on empirically derived equations, determined through work done out at the Royal Veterinary and Agricultural University (KVL) in, Copenhagen, Denmark. The empirical equations in the model are based on field measurements. The required input includes time series for the Reference ET, the leaf area index and the root depth, plus values for several empirical parameters that control the distribution of ET with the system, (Refsgaard & Storm, 1995).

First, net rainfall is calculated by subtracting water intercepted by the leaves. Net rainfall is added to the ground surface where it either infiltrates or ponds. Evapotranspiration is first removed from intercepted rainfall, followed by ponded water at the Reference ET rate. If the Reference ET is not yet satisfied for the current time step, then water is removed from the root zone via transpiration. The actual soil moisture content, soil field capacity and wilting point in each vertical cell are used to control the amount of transpiration. The vertical distribution of transpiration is controlled by the root depth and a root shape factor to distribute the ET within the root zone. The Kristensen and Jensen method can only be used with the Richards equation and gravity flow methods in the unsaturated zone.

2.1.3 Two-layer Water Balance Method

MIKE SHE also includes a simplified water balance method for both the unsaturated zone storage and ET. The Two-Layer Water Balance model divides the unsaturated zone into a root zone, from which ET can be extracted, and a zone below the root zone, where ET does not occur (Yan and Smith, 1994). Similar to the Kristensen and Jensen model, ET is extracted first from intercepted water (based on the leaf area index), then ponded water and finally via transpiration from the root zone, based on an average water content in the root zone. In the absence of ET, the average water content in the root zone decreases linearly with depth. However, ET reduces the water content in the root zone, creating unsaturated zone storage. The minimum water content in the root zone is the wilting point water content, but this can only occur when the water table is below the root zone. The Two-Layer Water Balance ET method requires time series for the root depth and the leaf area index, as well as the Reference ET.

The main purpose of the Two-Layer Water Balance ET method is to provide an estimate of the Actual ET and the amount of water that recharges the saturated zone. It is primarily suited for areas where the water table is shallow, such as in swamps and wetland areas. The model does not consider the flow dynamics in the unsaturated zone and, thus, is less suitable for areas with deeper and drier unsaturated zones. However, it is possible to calibrate the input parameters so that the model performs reasonably well under most conditions.

2.2 Unsaturated Flow

The unsaturated zone is usually heterogeneous and characterized by cyclic fluctuations in the soil moisture as soil moisture is replenished by rainfall and removed by evapotranspiration and recharge to the groundwater table. Unsaturated flow is assumed to be primarily vertical, since gravity dominates infiltration. Therefore, to reduce the computational burden, unsaturated flow in MIKE SHE is calculated only vertically. Although, this is sufficient for most applications, it may limit the validity of the flow description in some situations, such as on steep hill slopes, or in small-scale models with lateral flow in the unsaturated zone. The inherent heterogeneity of natural soils means that any unsaturated flow description must either ignore sub-grid variations and processes or devise strategies to account for them. As there is very little measurement information available at the grid scale, different strategies have been devised to derive large scale or effective parameters from small scale measurements (Refsgaard and Butts, 1999). Thus, the flow description in the unsaturated zone is effectively conceptual.

There are four solution options in MIKE SHE for calculating infiltration through the unsaturated zone:

- the full Richards equation, which requires relationships for both the moisture-retention curve and the effective conductivity,
- a simplified gravity flow procedure, which assumes a uniform, vertical unit-gradient and ignores capillarity,
- a simple two-layer water balance method for the root zone and the zone between the roots and the water table, and
- the calculation of net recharge by other means, which is then input directly as recharge to the saturated zone.

The full Richards equation is the most computationally intensive, but also the most accurate when the unsaturated flow is dynamic. The simplified gravity flow procedure provides a suitable solution when you are primarily interested in the time varying recharge to the groundwater table based on actual precipitation and evapotranspiration and not the dynamics in the unsaturated zone.

The simple two-layer water balance method is suitable when the water table is shallow, groundwater recharge is primarily influenced by evapotranspiration in the root zone, and the delay between precipitation and recharge to the saturated zone is small or not of interest. The direct input of net recharge is typically used when a more sophisticated model is required, such as DAISY (Hansen et al., 1990; Abrahamsen and Hansen, 2000) - a soil-plant-atmosphere model that is well suited for agricultural related studies.

2.2.1 Richards Equation

For vertical flow, the driving force for transport of water in the unsaturated zone is the vertical gradient of the hydraulic head, which includes both a gravity and a pressure component. In the unsaturated zone the pressure head is negative due to capillarity. Based on the continuity equation and Darcy's law, vertical flow in the unsaturated zone can be described by the so-called Richards equation. The Richards equation requires two functions - one for the pressure head as a function of saturation and the other for the hydraulic conductivity, also as a function of saturation. Evapotranspiration acts as a water sink in the upper soil layer and root zone portion of the unsaturated zone.

MIKE SHE calculates the unsaturated flow using a fully implicit finite difference solution (Refsgaard & Storm, 1995). For each time step, the upper boundary condition is either a constant flux (the rainfall rate at the ground surface), or a constant head (the level of ponded water on the ground surface). In most cases, the lower boundary is a pressure boundary determined by the water table. MIKE SHE includes an iterative coupling procedure between the unsaturated zone and the saturated zone to compute the correct soil moisture and the water table dynamics in the lower part of the soil profile. Particularly in this part of the model, it is important to account for the variable specific yield above the water table, as the specific yield depends on the actual soil moisture profile and availability of that water.

2.2.2 Gravity Flow

Gravity flow is a simplification of the Richards equation, where the pressure head term is ignored and the vertical driving force is due entirely to gravity. In this case, the continuity equation is solved explicitly from the top of the soil column downward. The flux out the bottom of the soil column is accumulated over the unsaturated zone time steps and added as a source to the saturated zone calculation at the start of the next saturated zone time step. The input to the model requires only the conductivity-saturation relationship.

Compared to the Richards equation, the gravity flow solution is several times faster and unconditionally stable. It is primarily used for coarse soils (capillary pressure is small) and when you are primarily interested in accurate evapotranspiration and delayed recharge to the groundwater table.

2.2.3 Two-Layer Water Balance

The Two-Layer Water Balance method divides the unsaturated zone into a root zone and a zone below the root zone. Infiltration discharges immediately to the saturated zone whenever the unsaturated zone storage is zero. The method simply calculates the amount of water that recharges the saturated zone, while accounting for unsaturated zone storage but ignoring the delay. This method is described in more detail in Section 2.1.3 of this chapter.

2.2.4 Lumped Unsaturated Zone Calculations

In principle, unsaturated flow should be calculated individually for every soil column in the model domain. However, for large models the unsaturated flow calculations can become the most time consuming part of the solution. The number of unsaturated zone calculations can be reduced by solving the flow equations once and applying the results to all similar cells (e.g. to those with the same rainfall, soil type, and depth to the groundwater table). Such lumping preserves the water balance, but may represent local dynamics less accurately.

2.2.5 Coupling to the Saturated Zone

The saturated and unsaturated zones are linked by an explicit coupling. That is, they are solved in parallel, rather than being solved in a single matrix with an implicit flux coupling of the unsaturated and saturated flow differential equations. The great advantage of explicit coupling is that the time steps for the unsaturated and saturated zones can be independent. This means that MIKE SHE can take advantage of the difference in the time scales of unsaturated flow (minutes to hours) and saturated flow (hours to days).

The coupling between unsaturated zone and the saturated zone is limited to a coupling between the entire unsaturated zone and the top calculation layer of the saturated zone. If the water table is below the bottom of the top saturated zone calculation layer, a free drainage boundary for the lower unsaturated zone boundary is assumed.

2.3 Overland Flow

Ponded water can occur, for example, when rainfall cannot infiltrate fast enough, when groundwater flows onto the surface (e.g. in wetlands), or when streams flood over their banks. Ponded water is routed downhill as surface runoff. The flowpath and quantity is determined by the topography and flow resistance, as well as losses due to evaporation and infiltration along the path it takes. Water flow on the ground surface is calculated using a finite-difference, diffusive wave approximation of the Saint Venant equations, or using a semi-distributed, slope-zone approach based on the Mannings equation.

2.3.1 Finite Difference Method

For two-dimensional surface water flow, it is common to simplify the governing equations by neglecting momentum losses due to lateral inflows, and local and convective accelerations. This is known as the diffusive wave approximation, which is implemented in MIKE SHE using a 2D, finite-difference approach.

Net rainfall, evaporation and infiltration are introduced as source/sinks, allowing the surface to dry out in more permeable soil areas. The solution assumes a sheet flow approximation, which may be crude for regional applications. Local depressions in the topography, as well as barriers, such as roads and levies, are conceptually modeled as detention storage. Detention storage restricts overland flow and allows water to more easily evaporate or infiltrate.

Ponded water is transferred to and from and the other hydrologic components at the beginning of every overland flow time step. Normally, overland flow is solved using the same time step as the unsaturated flow, whenever unsaturated flow is included in the model. Otherwise, the overland flow is calculated using the saturated flow time step. However, overland flow can be calculated using a completely independent time step, if necessary.

2.3.2 Semi-distributed Overland Flow

The semi-distributed model for overland flow in MIKE SHE is based on an empirical relation between flow depth and surface detention, together with the Manning equation describing the discharge under turbulent flow conditions. Such a method was implemented in the Stanford watershed model (Crawford and Linsley, 1966) and its descendants, such as HSPF (Donigian et al., 1995), and has been applied in other codes such as the WATBAL model (Refsgaard and Knudsen, 1996).

This semi-distributed conceptual overland flow uses a simplified representation of flow down a hillslope to describe surface flow within a topographical zone. The drainage of overland flow from one topographic zone to the next, and from the catchment to the river channels is represented conceptually as a cascade of overland flow areas. In the semi-distributed method, the current level of surface detention storage is continually estimated by iteratively solving the continuity equation. Overland flow interacts with the other process components, such as evapotranspiration, infiltration, and drainage to the channel network. These interactions are treated in the same manner in both the semi-distributed and the 2D finite-difference methods.

2.4 Channel Flow

Topography channels overland flow into small rivulets, streams and eventually rivers. Since, streams and rivers are found in low-lying areas, they also tend to be discharge points for groundwater. If topography and streambed bathymetry are known in enough detail, then channel flow can be calculated as two-dimensional surface flow (e.g. Sudicky et al., 2002). However, this requires very detailed elevation data and a large computational effort, even for small watersheds. The alternative is to assume that rivers are one-dimensional, which leads to a uniform surface elevation and flow rate across the channel. This is reasonable for most cases but may be untenable in detailed studies of river scour, bank erosion and other local phenomena where a detailed velocity distribution is important.

In MIKE SHE, the one-dimensional assumption is used and 1D channel flow is calculated by DHI's MIKE 11 program. MIKE 11 computes unsteady water levels and flow in rivers and estuaries using an implicit, 1D, finite-difference formulation. In the most advanced case, the complete non-linear equations of open channel flow (Saint-Venant) are solved using the 6-point Abbott-Ionescu method (Havnø et al. 1995). Alternatively, the diffusive wave, kinematic wave, and quasi-steady state approximations can be used. The program can be applied to branched and looped networks, and to quasi two-dimensional flow on flood plains. It is applicable to vertically homogeneous flow conditions ranging from steep rivers to tidally influenced estuaries. Both subcritical and supercritical flow can be calculated, depending on the local flow conditions. The flow over a wide variety of structures can also be simulated, such as broad-crested weirs, culverts, regulating structures, control structures, bridges and user-defined structures.

MIKE 11 also includes simple hydrologic routing methods, which are suitable when the detailed flow dynamics in the river are not of interest. The routing methods included in MIKE SHE are the Muskingum and the Muskingum-Cunge methods, as well as instantaneous flow routing. The former two methods account for the time it takes for a water pulse to move downstream, whereas the instantaneous method routes the flows through the system in a single time step.

2.4.1 Coupling between MIKE SHE and MIKE 11

The MIKE 11 river network is made up of digitized points (chainage locations) and calculation nodes (cross-section points). This river network is interpolated to the edges of MIKE SHE's rectangular grid for overland and saturated flow exchange with MIKE 11. Since the exchange occurs on the edges between grid cells, the more refined the MIKE SHE grid is, the more accurately the spatial distribuion of the exchange will be represented. The entire river system is always included in the hydraulic model, but MIKE SHE will only exchange water with the sub-set of the MIKE 11 river model that intersects the MIKE SHE overland flow/groundwater grid.

The calculated exchange flows are fed to MIKE 11 as lateral flow to or from the corresponding calculation points. Where floodplain inundation is allowed to occur, the water levels at the MIKE 11 calculation points are interpolated to specified MIKE SHE grid cells to determine if ponded water exists on the cell surface. If ponded water exists, then the unsaturated or saturated exchange flows are calculated based on the ponded water level above the cell.

2.5 Pipe and Sewer Flows

Urban drainage systems, sanitary and storm sewers affect surface and subsurface hydrology in urban areas. They can drain both overland flow and groundwater, and they can cause contamination of both surface water and groundwater. MIKE SHE can be coupled to the MOUSE sewer model (Mark et al, 2004, Lindberg et al, 1989) to simulate the effect of urban drainage and sewer systems on the surface/subsurface hydrology. MOUSE can simulate 1D, unsteady flow and water quality in branched and looped pipe networks, with a mixture of free surface and pressurized systems. Groundwater in MIKE SHE can be coupled to MOUSE's pipe network, based on the wetted perimeter and a leakage coefficient. MIKE SHE's overland flow can drain to open sewer canals and unsealed manholes. Lastly, drainage from MIKE SHE's saturated zone and paved areas can be discharged to a specific manholes.

2.6 Saturated Groundwater Flow

Groundwater plays a significant role in the hydrological cycle. During drought periods groundwater discharge sustains stream flow. Irrigation and abstraction can influence natural recharge and discharge, thereby changing the flow regime in a catchment. However, watershed scale models for planning purposes typically do not require detailed knowledge of water movement but information on water balances and trends. On the other hand, sub-watershed models for assessing wetland impacts of a new water works will require detailed analysis of groundwater/surface water interaction. This range of detail can be handled in MIKE SHE by using a fully implicit, 3D finite-difference scheme similar to MODFLOW, or a conceptual, linear reservoir approach.

2.6.1 Finite Difference method

In MIKE SHE, the spatial and temporal variations of the hydraulic head in the saturated groundwater zone is described mathematically by the 3D Darcy equation and solved numerically by an iterative implicit finite difference technique. There are two groundwater solvers available: a successive over-relaxation (SOR) technique and a preconditioned conjugate gradient (PCG) technique, which is nearly identical to the one used in MODFLOW (Hill, 1990).

Also similar to MODFLOW, MIKE SHE includes sub-surface agricultural drains. However, by routing the water collected in the drains to streams or sewers, MIKE SHE is able to use the drainage function to conceptually model the impact of near surface drainage on the surface water hydrograph.

2.6.2 Linear Reservoir method

Representing natural catchments with detailed groundwater models is often problematic due to data, parameter estimation and computational requirements. In this case, subsurface flow can often be described satisfactorily by a conceptual approach. The conceptual method can be viewed as a compromise between limitations on data availability, the complexity of hydrological response at the catchment scale, and the advantages of model simplicity.

In the linear reservoir method, the entire groundwater catchment is subdivided into groundwater sub-catchments. Each sub-catchment is divided into a series of serial, shallow reservoirs, plus one, or more, deep baseflow reservoirs. Each baseflow reservoir is further subdivided into two parallel reservoirs. The parallel reservoirs can be used to differentiate between fast and slow components of baseflow discharge and storage. Water will be routed through the linear reservoirs as interflow and baseflow and subsequently added to the river as lateral inflow in the lowest interflow reservoir.

2.7 Agriculture

Pasture and crops take up 37% of the Earth's land area and approximately 70% of all available fresh water is used for irrigation (UNESCO, 2003). However, in most settings water for irrigation is neither metered, nor easily forecast because irrigation is applied only when it is required. Irrigation is further complicated by water rights and complex management rules. MIKE SHE's Irrigation Module can simulate a wide range of irrigation practices with multiple sources. Irrigation management can be simulated using distributed temporal crop water demand. It includes the conjunctive use of surface and groundwater with the option of setting irrigation priorities and control strategies based on soil moisture levels.

MIKE SHE is also frequently used with DAISY, a detailed soil-plant-atmosphere model (Hansen et al., 1990; Abrahamsen and Hansen, 2000). DAISY has been optimized to work as an open and flexible agro-ecosystem modeling system, well suited for agricultural related studies. DAISY can be used to model changes in crop yield as a function of water and nitrogen availability, irrigation optimization and nitrate and pesticide leaching. When used with MIKE SHE, DAISY replaces MIKE SHE's unsaturated zone and vegetation/ET processes.

2.8 Water Quality

Advection/dispersion methods are used to address problems where the exchange of contaminants between the hydrologic processes is important - that is transport in and exchange between overland flow, channel flow (MIKE 11), unsaturated flow, and saturated groundwater flow. The advection/dispersion equation is solved by the explicit QUICKEST method (Leonard, 1979). MIKE SHE can simulate transport of water and solutes in macropores, with exchange to the surrounding bulk matrix. It can also simulate equilibrium and kinetic sorption (including hysteresis), first-order decay that depends on soil temperature and soil moisture content, sequential biodegradation, and plant uptake with transpiration. In addition to the advection/dispersion method, a random walk particle tracking method is also available for the saturated groundwater zone.

Ecological modeling is a relatively immature discipline that involves many different processes and networks of interacting subsystems. To this end, a general ecological modeling tool (ECOLab) has been developed that enables engineers and ecosystem experts to develop their own ecosystem models appropriate to site specific ecological conditions. ECOLab is now linked to MIKE 11, to address problems such as eutrophication, and the retention and removal of nutrients and pollutants in wetlands.

3 MIKE SHE Graphical user Interface

The MIKE SHE user interface has been designed to provide a logical and intuitive workflow. This is very important for most users because it eases the model application work and should therefore not be underestimated., in particular when most applications of MIKE SHE involves many processes and many data. Some of the features that contribute to a good interface are:

- Dynamic navigation tree, which gives the user a complete overview of your model while hiding irrelevant items
- Logical, dynamic dialogs, which allows the user to concentrate on the required data, since sub-dialogs contain only relevant parameters
- Top-down/Left-right model design, which leads the user through the model development in a natural manner
- Automatic data checking, which saves the users time trying to decipher obscure run-time errors
- On-line documentation, allows the user to find answers quickly during the working process

It is also important that the user feels a natural progression from conceptual to numerical model so it becomes easy to move from the raw data via the conceptual model to the results and back again. Traditionally, most codes have been designed such that the input data is dependent on the schematization and the spatial resolution of the model. MIKE SHE provides some advantages in terms of:

- Stores the link to the original data and not the original data itself, which gives a high flexibility, for example
    - Run multiple models from the same data set,
    - Update your data and update all your models automatically
    - Run rapid sensitivity analyses on your model domain, grid spacing, layer specifications, etc.
    - Use your favorite editor for managing your data,
- GIS integration – the seamless link to ArcView shape files for all distributed parameters and overlays saves you time and effort
- Geo-objects for natural, object-oriented model design – input your natural geologic formations (including lenses!) and let MIKE SHE take care of the conversion to the numerical grid
- Link models together – easily link local-scale models to regional-scale models, or multiple regional models together to include interactions between watersheds

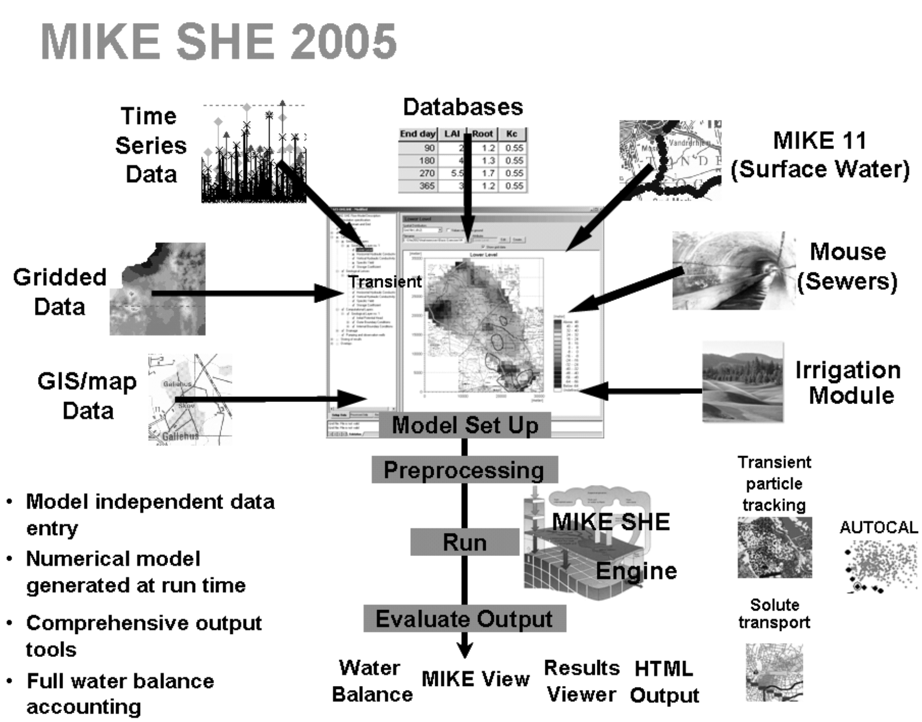


Figure 3. Schematic presentation of editors and work process in connection with a MIKE SHE Application.

4 Conclusion

This paper is intended as a background note in conjunction with an oral demonstration of MIKE SHE code. It describes briefly the processes and its design. MIKE SHE has been developed over many years with close interaction and numerous feedback from many users using MIKE SHE for various types of integrated water resources modeling around the World.

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